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Usability of 3D Perspective Displays

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Overview

- Determine how 3D perspective displays affect user performance
  - Representation of space: 2D vs. 3D views
  - Representation of objects: 2D vs. 3D symbols
- Focus on human factors and displays research
  - Select studies with military-relevant tasks, displays, and objects
  - Look at effectiveness of 3D perspective view vs. 2D plan view
  - Assess importance of monocular and binocular depth cues (e.g., drop-lines, shading, stereopsis)
  - Determine if performance varies as a function of task
    - » Recognition of objects
    - » Recognition of relative spatial locations of objects
    - » Recognition of physical and/or functional connections between objects

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Considerations in Using Perspective Displays

- **Advantages**
  - Provide a visual representation of depth information
  - May be more intuitive and natural to use (and easier to operate)
  - Are preferred by users
  - May present a clearer picture of tactical information (eliminate need to search text boxes for attributes such as altitude and to do mental integration of information from different views)
- **Disadvantages**
  - Are prone to distortion (due to distortions associated with parameters of perspective)
  - Are prone to clutter (less display area near horizon so more objects are packed into smaller area; addition of depth cues such as drop-lines increase number of objects displayed)
  - Are poor for precision tasks (e.g., realistic icons do not scale well; distant objects may be too small to be recognizable)

Impact of 2D vs. 3D Displays on Performance (1)

- **Research provides mixed results concerning performance benefits of 3D perspective displays compared to 2D plan-view displays**
  - **Aggregation of results difficult because studies differ in tasks and displays used**
  - **Studies of 3D displays vary in depth cues present vs. manipulated (e.g., drop-lines)**
  - **Results may reflect differences in the performance demands of a task rather than the nature of the displays themselves**
  - **Users may prefer to use displays that hinder rather than enhance their performance**

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Impact of 2D vs. 3D Displays on Performance (2)

- **In general, perspective displays are useful for understanding shape/layout of complex objects but impair judgments of relative position of objects**
  - **Bemis et al., 1988 - Performance in air intercept control was better with a 3D view compared to a 2D view**
  - **Baumann et al., 1997 - Performance was better with a 3D view when the task was to identify most (70%) aircraft but better with a 2D view when the task was to identify all aircraft**
  - **Smallman et al., 1999 - Situation awareness (SA) was better during the first 4 min. of scenario monitoring with a 2D view, but increased faster with a 3D view during the first 5 min. and was equivalent to 2D view after 9 min. of monitoring**
  - **St. John et al., 2000 - Performance in understanding terrain shape and layout was better with a 3D view, but performance in selecting the higher terrain elevation was better with a 2D view**

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Investigation of Depth Cues in 3D Displays

- **Determine which depth cues in computer-generated perspective displays will minimize bias and distortion in user judgments of spatial information**
  - **Monocular cues**
    - **Light (e.g., luminance/brightness, shadows, color)**
    - **Texture (e.g., density gradients, linear perspective)**
    - **Occlusion/interposition (e.g., size-distance invariance, object size)**
    - **Motion (e.g., motion parallax, kinetic depth effect)**
  - **Binocular cues (e.g., binocular disparity/stereopsis)**
- **User tasks**
  - **Judge the separation (relative depth/altitude) between a reference object and a target object located above a ground plane**
  - **Judge the time to collision for two objects or the time for an object to collide with an observer**

Impact of Depth Cues on Performance (1)

- User performance was improved by the presence of
  - Yeh & Silverstein, 1992; Hendrix & Barfield, 1997 - Eye-point elevation angles between 15 and 45 degrees (i.e., the elevation of the computer graphics virtual camera above the computer-generated scene)
  - Delucia, 1995 - Drop-lines (i.e., ground-intercept information) and pictorial relative size (i.e., objects equal in projected size)
  - Hendrix & Barfield, 1995 - For depth judgments: Drop-lines alone and with texture (i.e., wire-frame grid), and location of target object relative to reference object (i.e., target object in front was better)
  - Barfield, 1998 - Ability to rotate the perspective scene interactively (motion parallax)

Impact of Depth Cues on Performance (2)

- **User performance was not affected by the presence of**
  - **Hendrix & Barfield, 1995 - For depth judgments: texture (i.e., wire-frame grid), drop-shadows for objects**
  - **Hendrix & Barfield, 1995 - For altitude judgments: Drop-lines, texture, drop-shadows for objects, location of target object relative to reference object - results may be due to "favorable viewing conditions"**
  - **Barfield, 1998 - Shading and shading with shadows added to a wire-frame grid - results may be due to use of drop-lines in all displays**
- **User performance was not affected by the presence of binocular depth cues if judgments could be made easily from the monocular cues available**
  - **Yeh & Silverstein, 1992; Barfield & Rosenberg, 1995 - Stereopsis had positive effect on performance**
  - **Hendrix & Barfield, 1995; Hendrix & Barfield, 1997 - Stereopsis had no effect; may be due to presence of drop-lines**

Object Representation

- Non-realistic symbols
  - NTDS symbols - object represented as frame; shape and color indicate threat and environment; address engagement domain
  - MIL-STD 2525 symbols - object represented as frame with color fill and icon; shape and color indicate threat and environment; address engagement and force domains
- Realistic icons
  - 2D realistic icons - object represented pictorially, top-down view and north-oriented
  - 3D realistic icons - object represented pictorially, oriented in direction of movement

MIL-STD 2525 Background

- Aug 93 - MCEB directed development of symbology standard using "accelerated" process
- Feb 94 - Symbology Standards Management Committee (SSMC) chartered
- Sep 94 - MIL-STD 2525 Version 1 (Draft) published
  - Based on STANAG 2019 and FM 101-5-1 for force domain and STANAG 4420 and NTDS for engagement domain
  - Used frame shapes consistent with NTDS
- Dec 96 - MIL-STD 2525A published
  - Revisited frame shapes per Army/Marine Corps request
  - Used frames shapes consistent with FM 101-5-1 per MCEB
  - Validated via questionnaire, rather than operator testing, per MCEB
- Jan 99 - MIL-STD 2525B published
  - Corrected errors in 2525A, added symbols for specific communities
  - Provided complete set of tactical graphics

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Key Requirements of MIL-STD 2525

- **Defines symbol composed of frame, fill, and icon, with text/graphic modifiers**
- **Requires use of standard frame shapes and colors but allows systems to extend as needed to meet requirements**
- **Supports multiple options for display (e.g., render as frame/fill, frame only, dot)**

<u>NTDS</u> <u>2525</u>

Color coding				
	Blue	**Friend**	**Friend**	
	Red	**Hostile**	**Hostile**	
	Green		**Neutral**	**Neutral**
	Yellow		**Unknown**	**Unknown**
Shape coding				
	Circle		**Friend**	**Friend (Sea)**
	Rectangle		**Friend (Ground)**	
	Diamond		**Hostile**	**Hostile**
	Square		**Unknown**	**Neutral**
	Quatrafoil		**Neutral**	**Unknown**

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Impact of Object Representation on Performance

- **NATO STANAG 4420 (similar to MIL-STD 2525) vs. NTDS**
  - NATO Testing, 1991 - Symbol recognition better with NATO symbols than with NTDS symbols
  - SODA Project, 1991-1994 - Visual search better with NATO symbols than with NTDS symbols; no differences between symbols in recall
- **3D and 2D realistic icons vs. MIL-STD 2525 symbols**
  - Smallman et al., 1999 - 2525 symbols were learned faster and with fewer errors than were 3D and 2D realistic icons; icons provided better situation awareness for altitude, attitude, and heading attributes than did the 2525 symbols
  - Smallman et al., 2000 - 2525 symbols were named faster and with fewer errors than were 3D and 2D realistic icons, even though participants indicated they preferred to view icons; no differences between icons and symbols in platform categorization task

Implications for Display Design

- **Representation of display space**
  - Support both perspective and plan views so users can select the display that is more appropriate for a specific task or judgment
  - Provide artificial depth cues (e.g., drop-lines) to reduce distortion; include a show/hide capability so users can manage display clutter
  - Allow users to rotate the view interactively so they can optimize the position of the objects being judged
  - Consider providing binocular depth cues (stereopsis) if monocular cues would be insufficient to support accurate judgments
- **Representation of display objects**
  - Render objects in a uniform size unless uniformity would be counterintuitive
  - Ensure that the manner in which objects are represented supports the task being performed
    - Provide 2D symbols if rapid, accurate identification is required
    - Provide 3D icons if monitoring spatial attributes (e.g., altitude) is required